The following presentation is a synopsis of the below presentations that discuss the structural similarities between the Sagaing and San Andreas Plate-Boundary faults, adjacent folds and hydrocarbon traps, and the petroleum setting and potential of onshore Myanmar (Burma).

Thomas L. Davis, Geologist
www.thomasldavisgeologist.com
www.geologicmapsfoundation.org

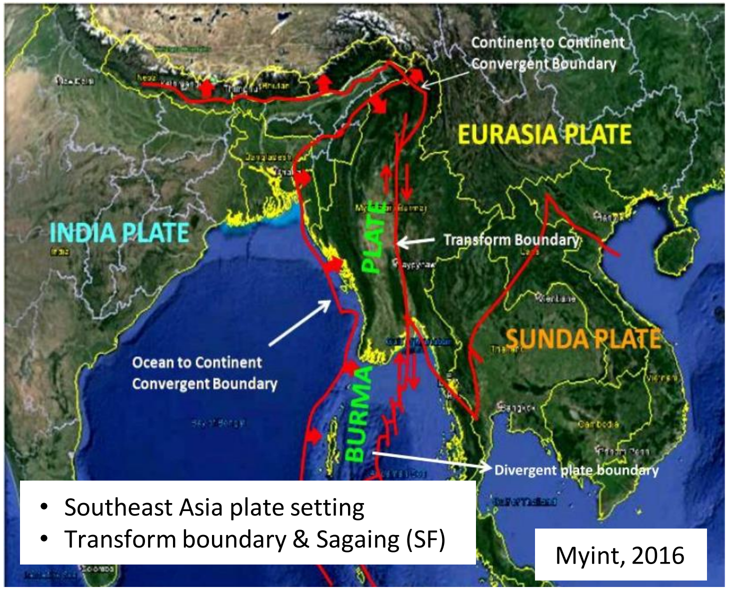
Davis, T.L. and Namson, J.S., 2017, Hydrocarbon traps and structural style in a transpressional belt: the San Andreas fault and deformed California oil basins can provide exploration guidance along the Sagaing fault and adjacent fold belts, Myanmar: AAPG/EAGE/MGS 3, Yangon, Myanmar, 22-24 February 2017, http://www.searchanddiscovery.com/abstracts/pdf/2017/90294apr/abstracts/ndx_davis.pdf

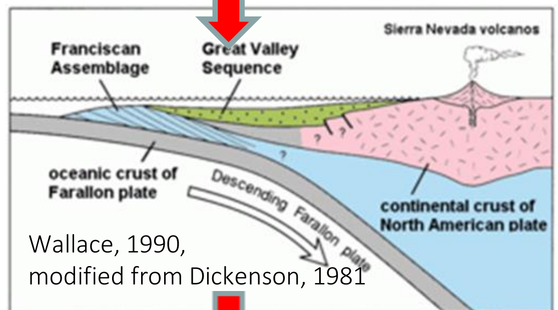
Davis, T.L., 2018, Petroleum geology comparison of the San Andreas fault plate boundary, California, USA to the Sagaing fault plate boundary, Myanmar (Burma): structural style, oil field traps, tectonic setting and basin development, Pacific Section AAPG Convention, April, 2018, Bakersfield, CA

Davis, TL., 2018, Petroleum geology comparison of the San Andreas fault plate boundary, California, USA to the Sagaing fault plate boundary, Myanmar (Burma): structural style, oil field traps, tectonic setting and basin development: Coast Geologic Society Meeting, December, 17, 2018, Ventura, CA, http://www.coastgeologicalsociety.org/

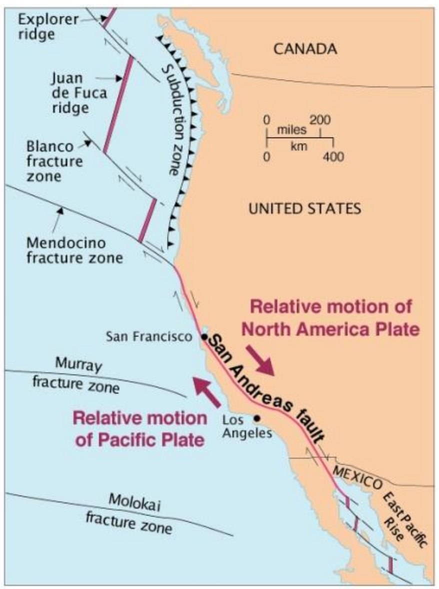
Petroleum geology comparison of the Sagaing fault (SF) plate boundary, Myanmar (Burma) to the San Andreas fault (SAF) plate boundary, California, USA with emphasis on the structural style, oil field traps, tectonic setting and basin development

Thomas L. Davis, Consulting Geologist, USA,
www.thomasldavisgeologist.com

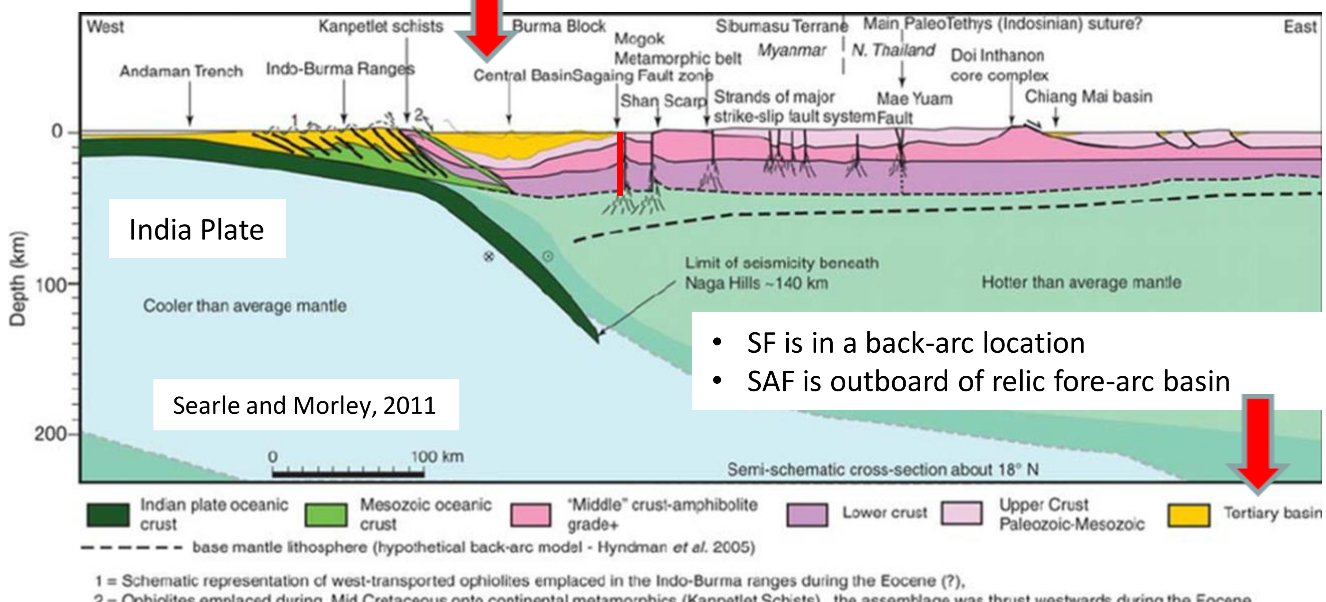




Myanmar's present plate-tectonic setting is approximately similar to the North American/Farallon plate setting during Jurassic-Eocene time. Red arrows show the positions of the forearc basins.

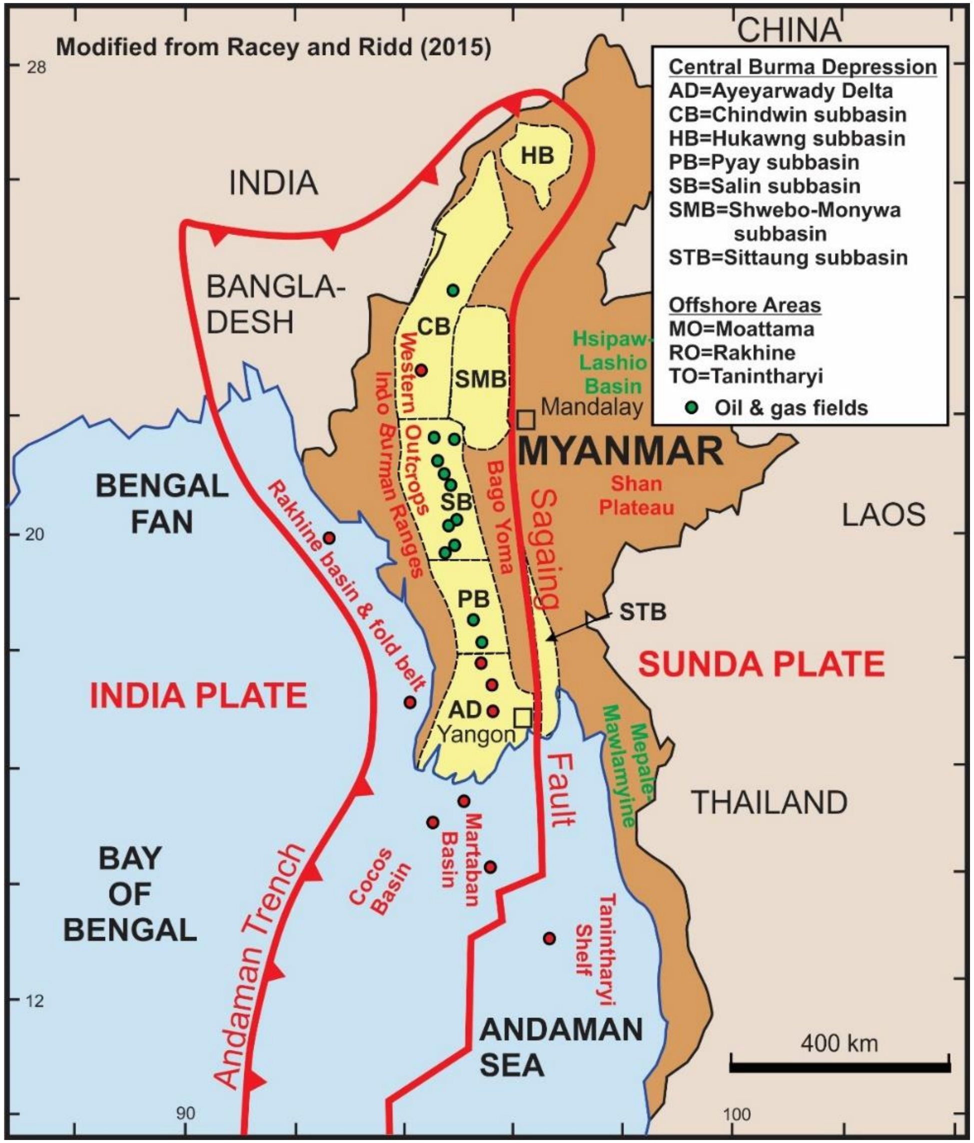


Cartoon sketch of the present-day Pacific Plate-North American Plate boundary showing the San Andreas fault. (USGS, 2017, Public domain).



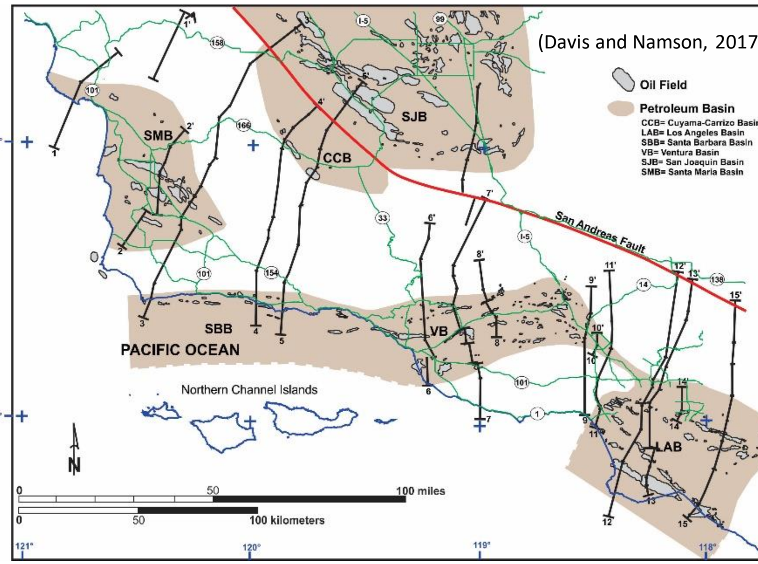
- SF is in a back-arc location
- SAF is outboard of relic fore-arc basin

Petroleum geology analogs and experience along the SAF plate boundary can provide guidance for oil exploration and field development in CBD because of the structural similarities (presentation is limited to onshore Myanmar).



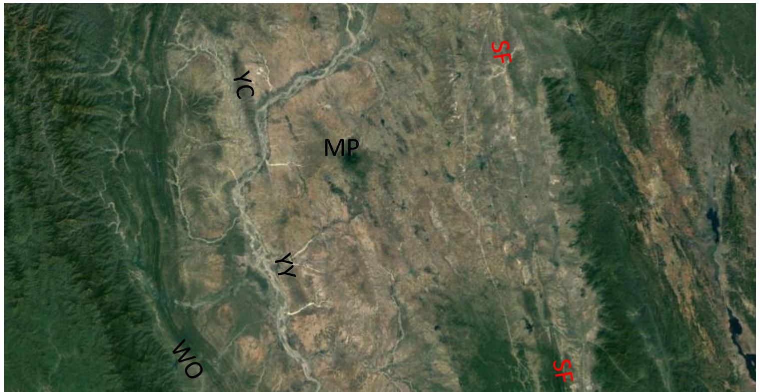
Petroleum Geology Similarities:

- ~300 km right-lateral-offset since Miocene on SF and SAF
- Convergent strike-slip (transpression) with adjacent fold and thrust belts
- Dominantly structural hydrocarbon traps in the Central Burma Depression (CBD) and Neogene Basins of CA
- Many traps are convergent and formed since the late Miocene
- CBD and CA oil basins have very thick Cenozoic sedimentary sections (up to 15 km).
- CBD and CA oil basins have active petroleum systems that began in the Miocene.
- Onshore hydrocarbon production is confined to the CBD

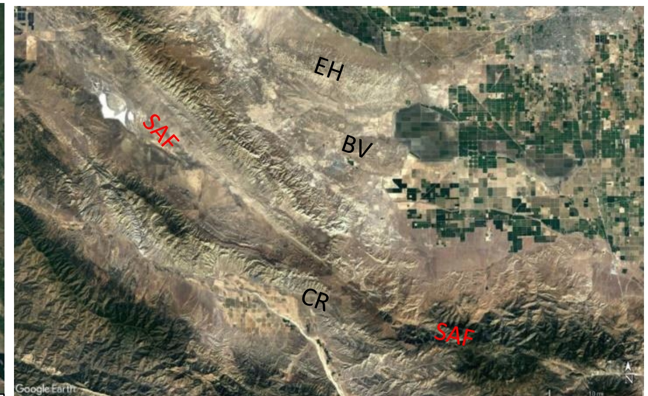


Namson and Davis southern California cross sections. available here: http://www.thomasldavisgeologist.com/downloads-for-free.html

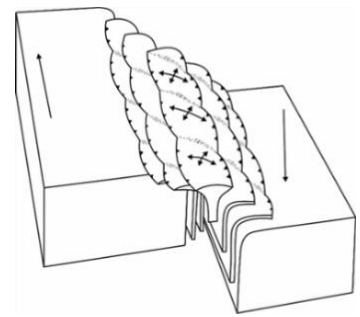
Anticlinal traps adjacent to the SF and SAF, transpression and drag models, strain partitioning, flower structures vs fault-ramp anticlines. Examples from Myanmar and California.



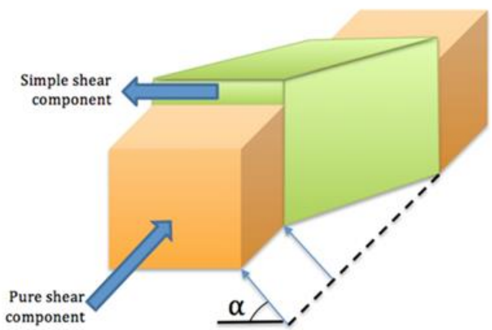
Salin Sub-basin, CBD: MP=Mt. Popa, SF=Sagaing Fault, WO=Western Outcrops, YC=Yenangyat-Chauk, YY=Yenangyaung. Structures and oil fields summarized in Racey and Ridd (2015) and Pivnik et al. (1988).



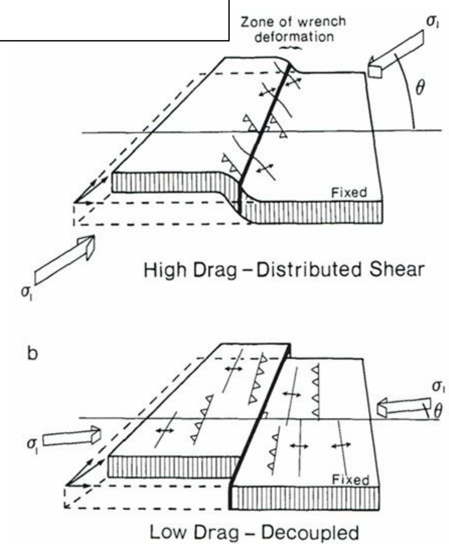
Cuyama and SW San Joaquin basins: BV=Buena Vista Hills, CR=Caliente Range, Elk Hills, SAF=San Andreas fault. Faults, structures and oil field traps summarized in Namson and Davis (1988), Davis et al. (1988, 1996), and Davis and Namson (2017).



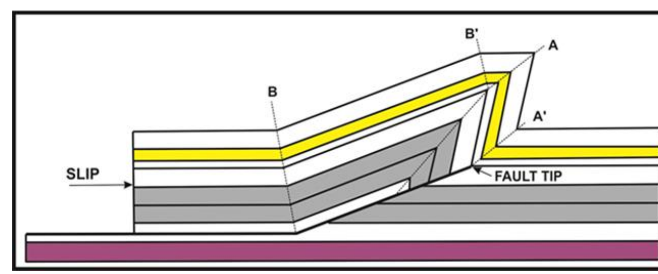
An idealized model of a positive flower structure along a convergent wrench fault (Lowell, 1972).



Simple model for *transpression*: strike-slip zone with an additional and simultaneous shortening across the zone (Sanderson and Marchini, 1984).



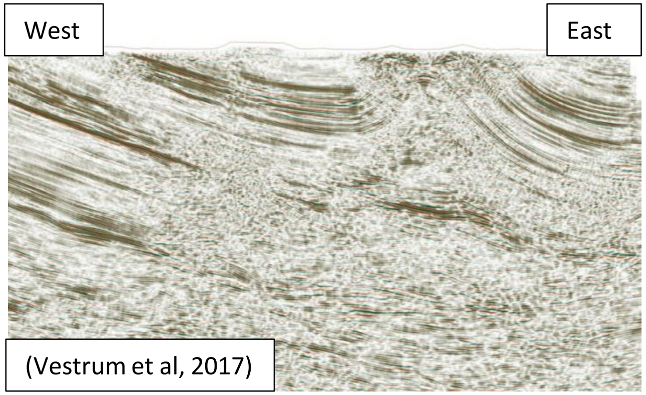
High drag vs low drag models along a transpressive boundary (Mount and Suppe, 1987), strain partitioning, fault-normal compression



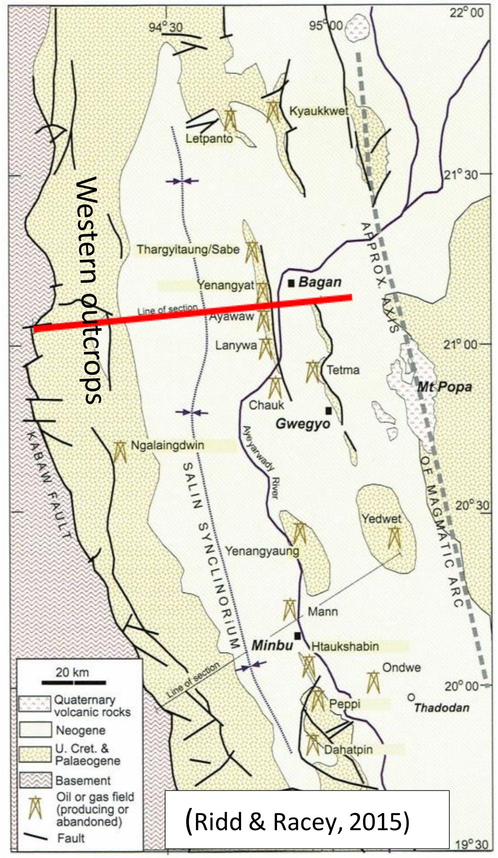
Shown is a fault-ramp fold (fault propagation fold; Suppe and Medwedeff, 1990).

Structure of the CBD, and Salin, Pyay and Chindwin Sub-basins

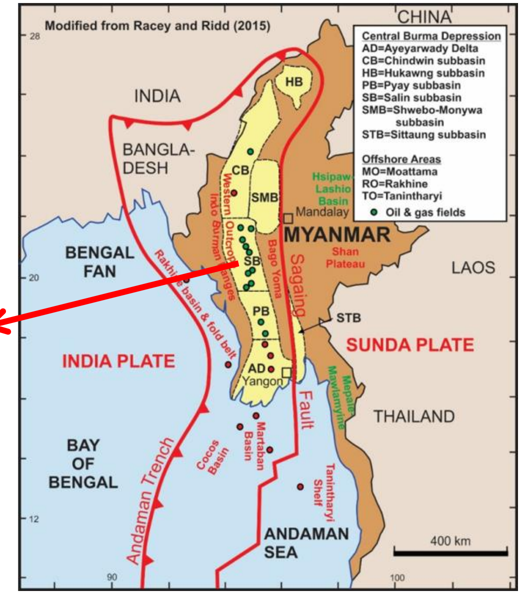
Western outcrops (Pyay Sub-basin, MOGE4)



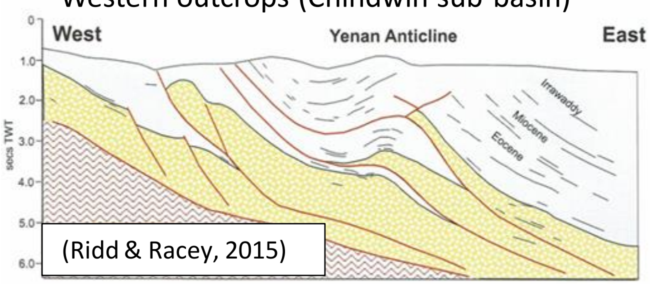
(Vestrum et al, 2017)



(Ridd & Racey, 2015)

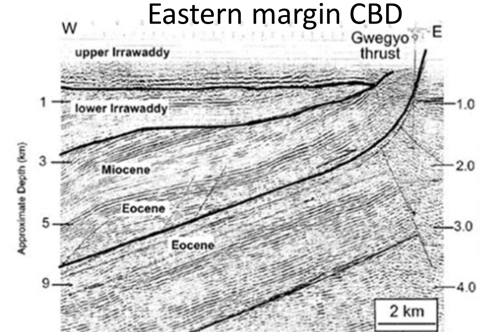


Western outcrops (Chindwin sub-basin)

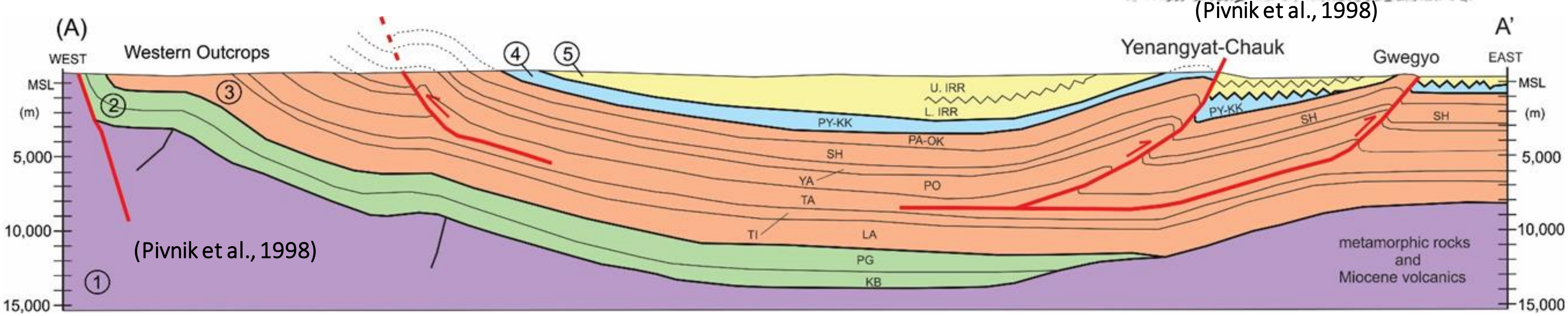


(Ridd & Racey, 2015)

Eastern margin CBD



(Pivnik et al., 1998)

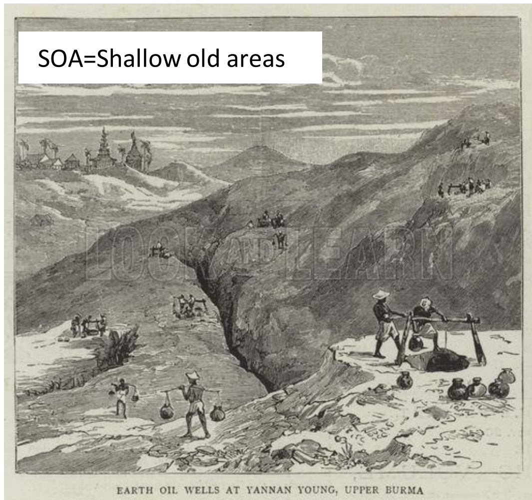


(Pivnik et al., 1998)

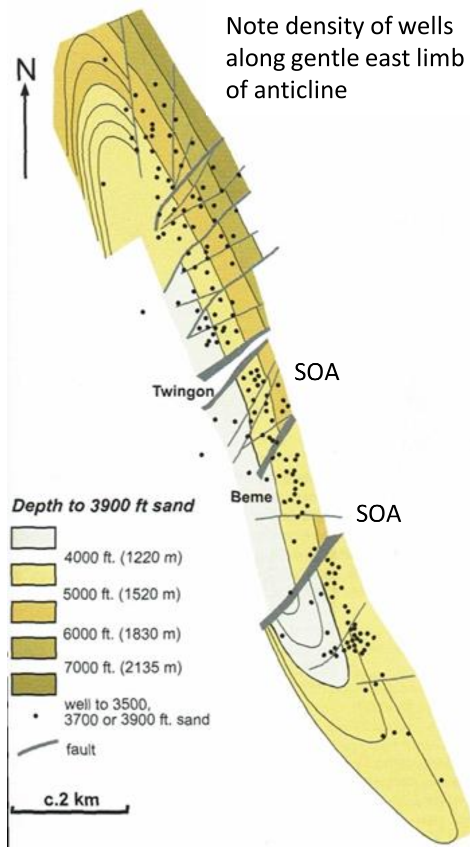
Yenangyaung oil field (CBD), one of world's oldest fields, and its interesting history

- The British found a flourishing oil extraction industry in the town of Yenangyaung in 1795, exported its first crude oil in 1853
- Geologist Thomas Oldham developed the 'anticlinal' theory of oil accumulation from a visit to Yenangyaung in 1855
- Peak production 16,000 BOPD in 1918, 1,840 BOPD in 2012, waxy crude, 33-38^{o} API, upper Olig-mid Mio sand reservoirs
- Estimated ~200 MMBO ultimate recoverable before initiation of Improved Petroleum Recovery Contracts (IPRC)

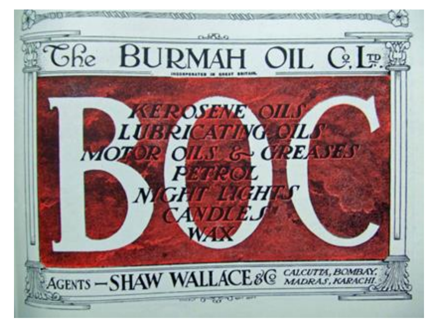
SOA=Shallow old areas



Note density of wells along gentle east limb of anticline

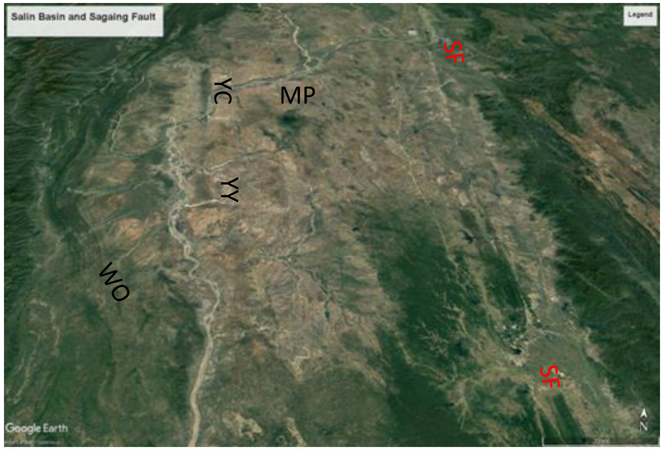


The London-based Burmah Oil Company (BOC) was established in 1871 and began production in the Yenangyaung field in 1887 and the Chauk field in 1902. Many of the early expats were American.

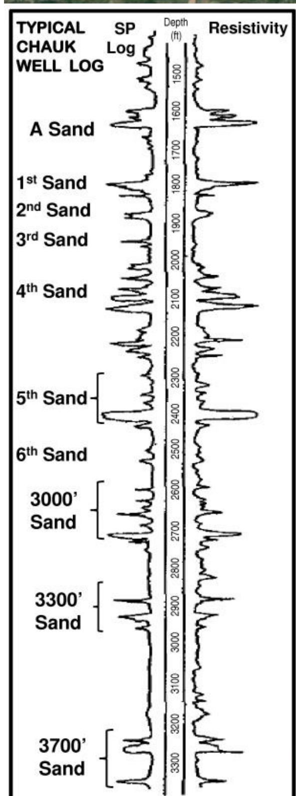


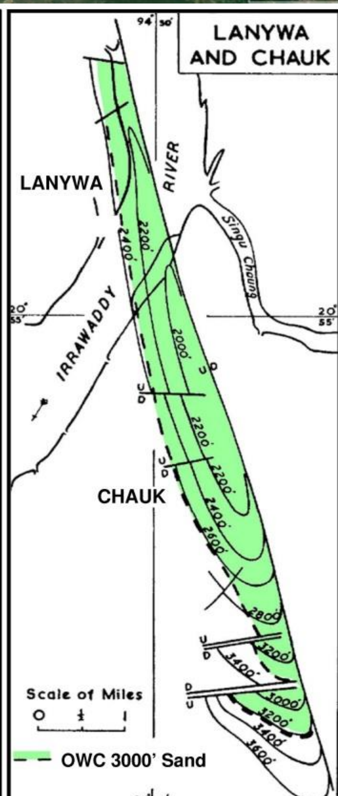
Japanese troops of the 33rd Division in the Yenangyaung oilfields of the Irrawaddy valley, Burma, WWII.

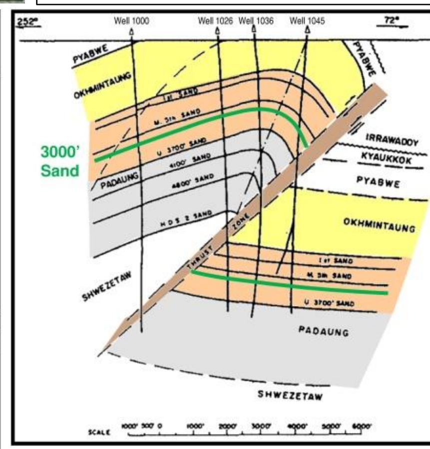
Opportunities, for example, Improved Petroleum Recovery Contracts (IPRC) along Chauk-Yenangyaung structural trend, http://www.interraresources.com/operations_myanmar.asp



August 2017, Gold petrol Joint Operating Company (China) extended for 11 more years IPRCs on Chauk and Yenangyaung fields with MOGE. Interra (Singapore) holds 60% WI in both blocks and Goldpetrol. Chauk and Yenangyaung are the two largest onshore producing fields in Myanmar. During 2017, the combined gross production for both fields was 837,823 barrels of oil. An update of reserves and resources for both the Chauk and Yenangyaung fields will now proceed.







Reservoir Depth: 365 m (1,200') to 1,127 m (3,700')

Gross Pay thickness : up to 500 m (1640')

Number of producing sands: ~35

Average net pay/sand: 3 m to 15 m

Porosity: 13% to 25%

Permeability: 40 mD to 3,210 mD

Average water saturation: 27%

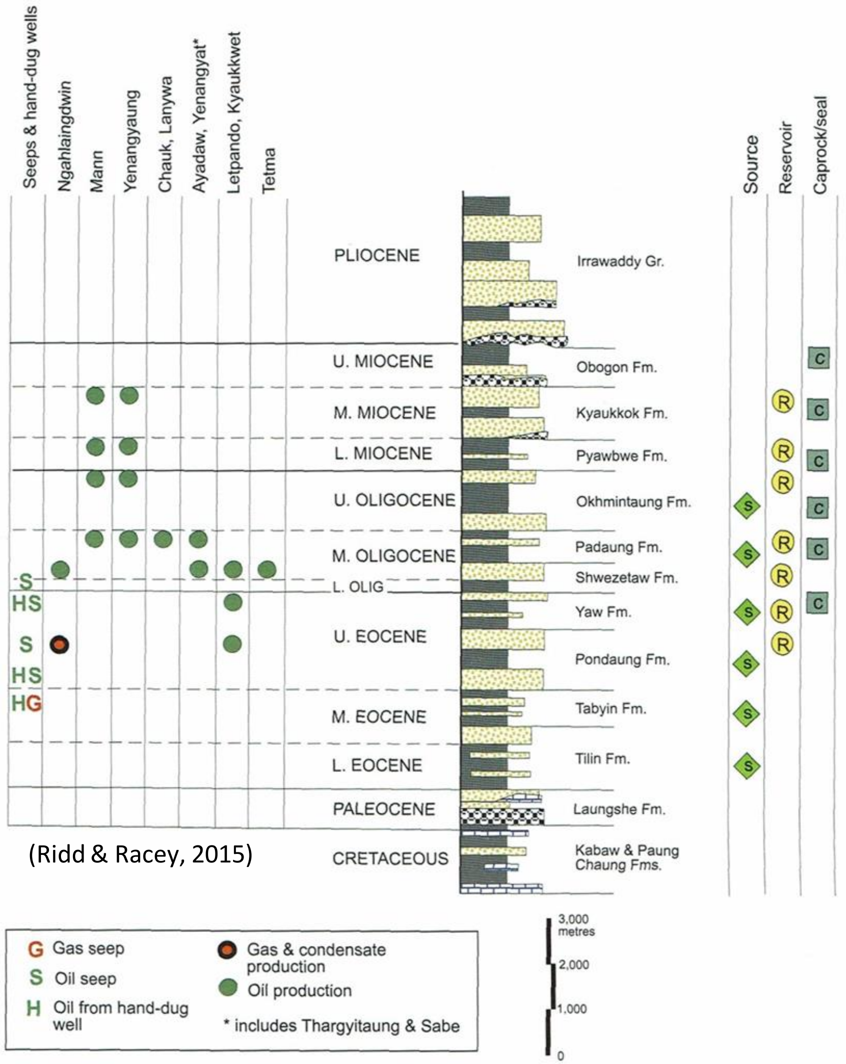
OOIP: 570 MMbbl

Oil: 39.6° API.

After Tainsh, 1950 and Khin, 1991

Stratigraphy of Salin Sub-basin CBD, and Tertiary Onshore Petroleum System (TOPS)

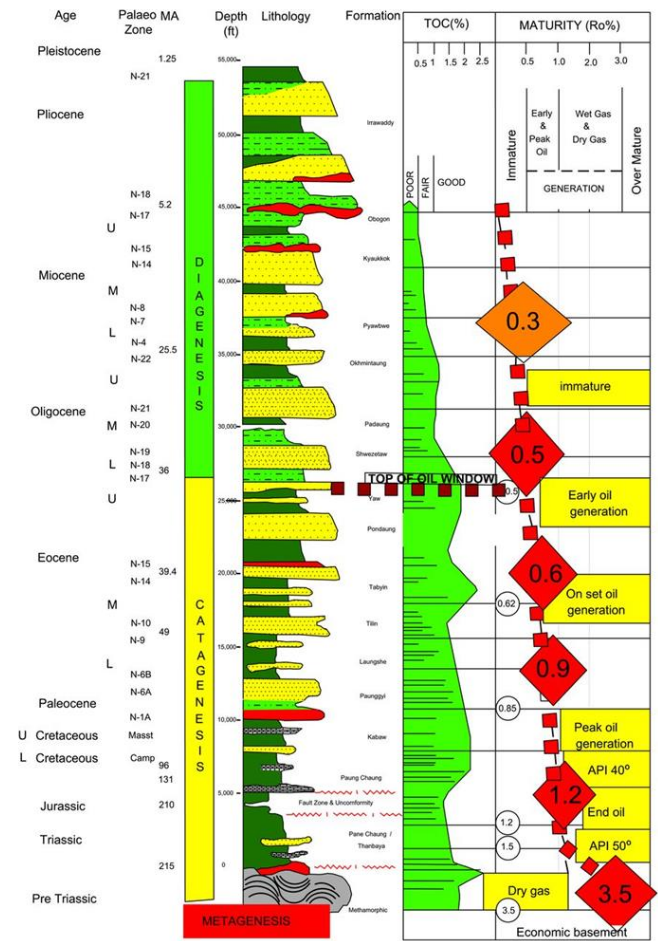
- **Salin Sub-basin stratigraphy (representative of CBD):**
  - Mostly shallow marine, brackish-water and nonmarine deposits
  - Eocene-Oligocene shallowing upward sequence (source beds)
  - U. Eocene-middle Miocene sand reservoirs and shale seals



(Ridd & Racey, 2015)

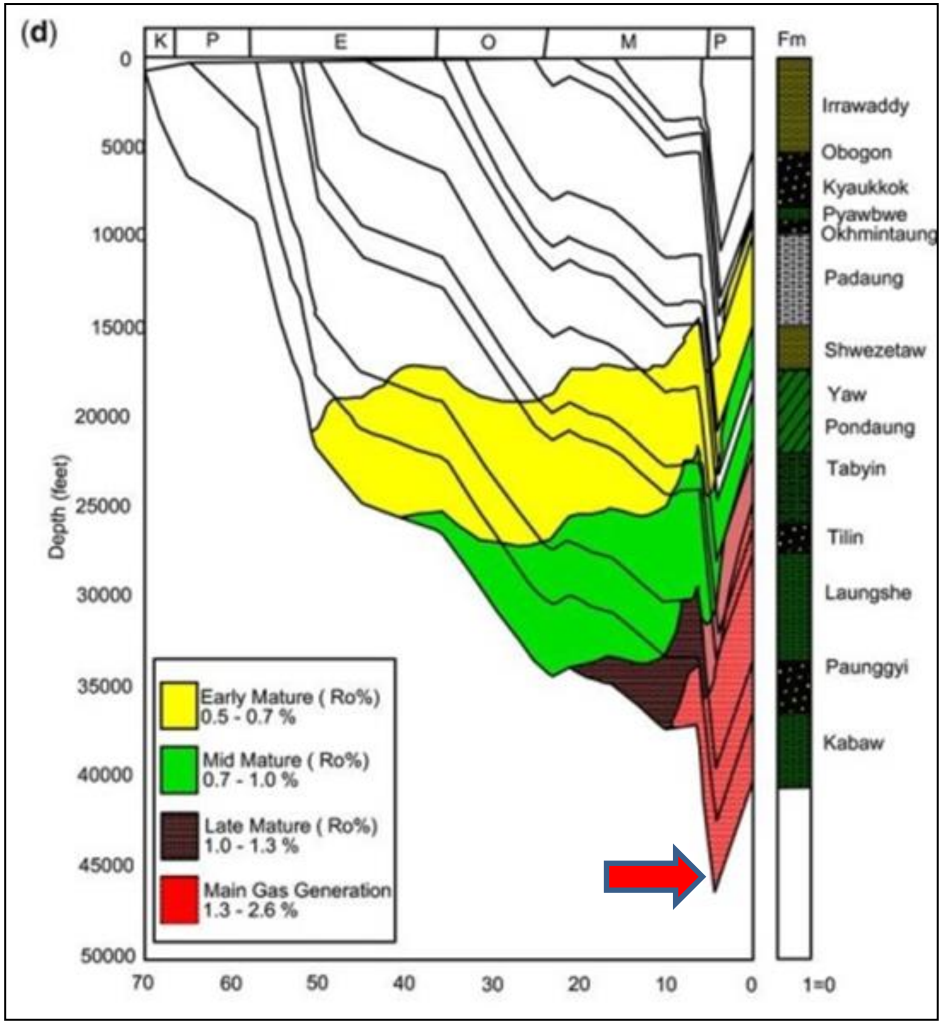
Tertiary Onshore Petroleum System (TOPS) in CBD

- Hydrocarbon production to date only from TOPS
- Inferred petroleum systems of Mesozoic and Paleozoic ages
- TOPS: Crude oil are related
- Source are upper Cretaceous through Oligocene shale units
- Organic sources are land plants, algal and amorphous
- Thermogenic and biogenic derived gases
- Biogenic gas mostly in Quaternary section

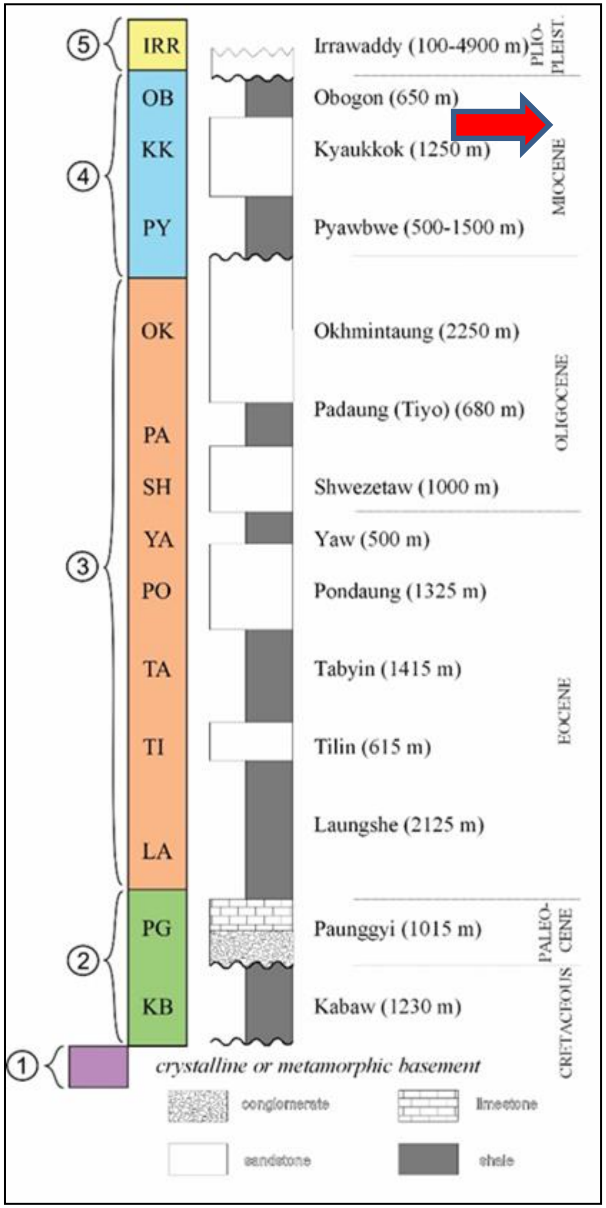


(Than Htut, 2017)

Salin sub-basin stratigraphy and petroleum system



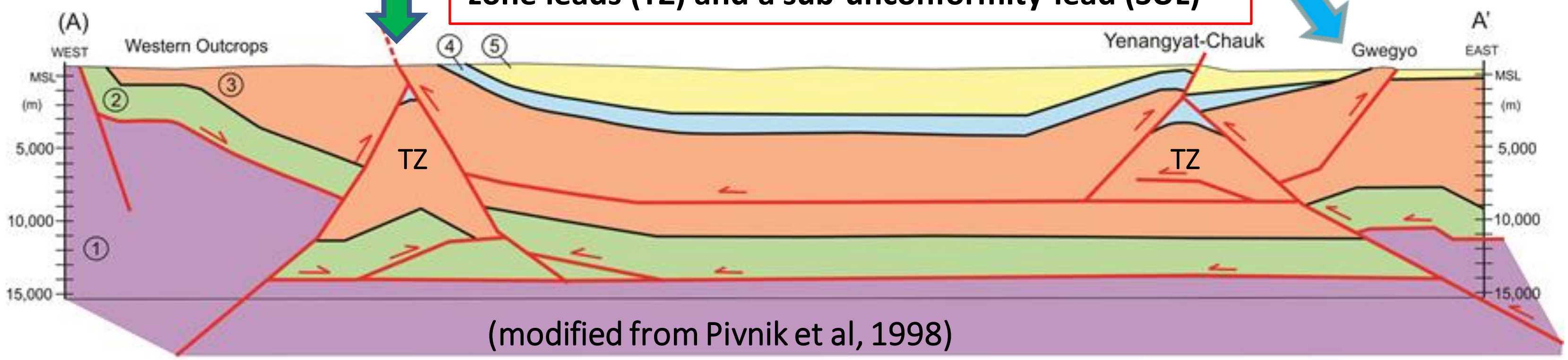
Salin sub-basin geohistory (Than Htut, 2017) shows rapid subsidence and high depositional rate followed by uplift (onset of transpression and trap formation)



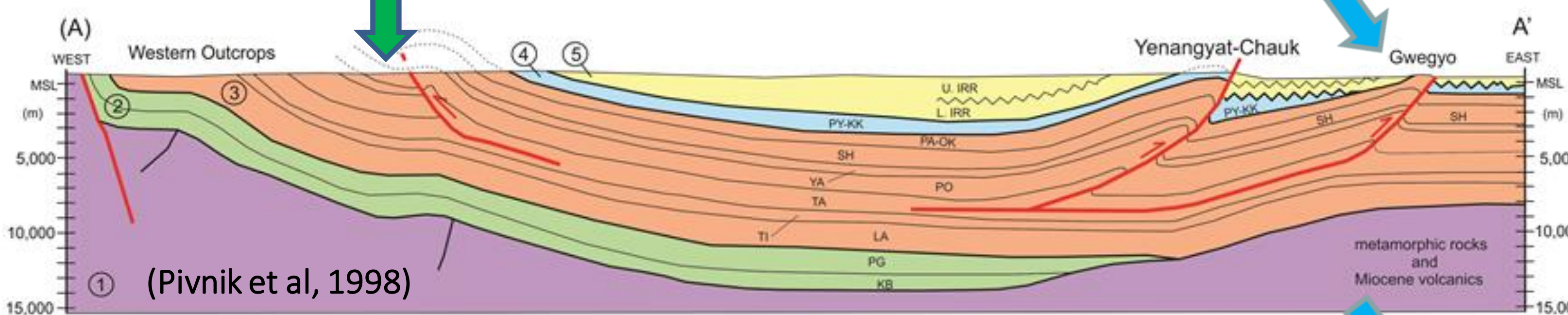
Uplift

Subsidence and high rate of deposition

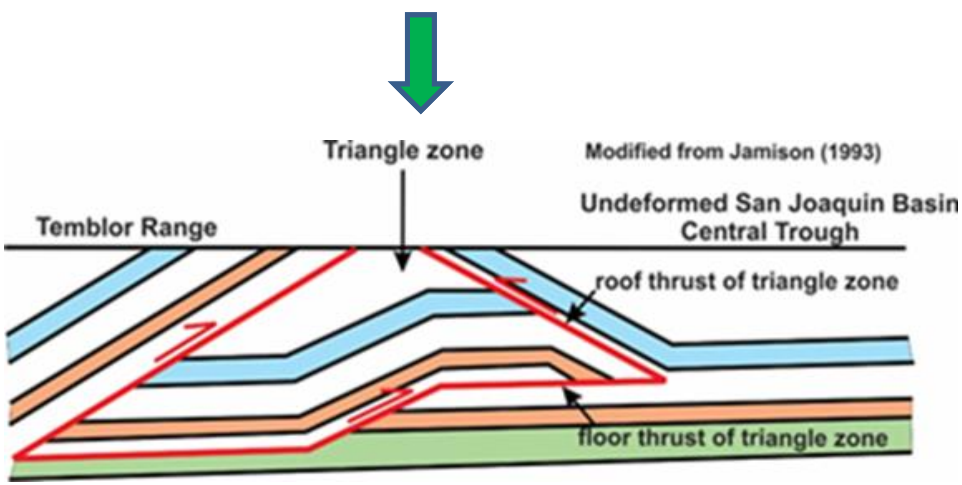
Structure of the Salin Sub-basin (CBD) with triangle zone leads (TZ) and a sub-unconformity lead (SUL)

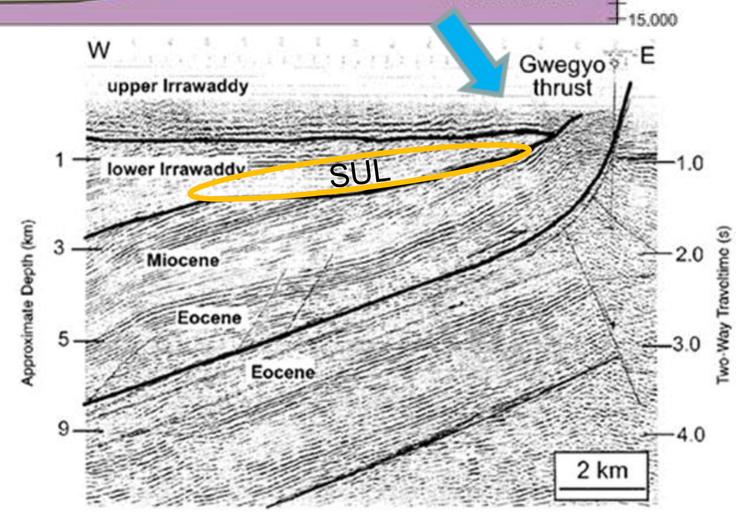


(modified from Pivnik et al, 1998)



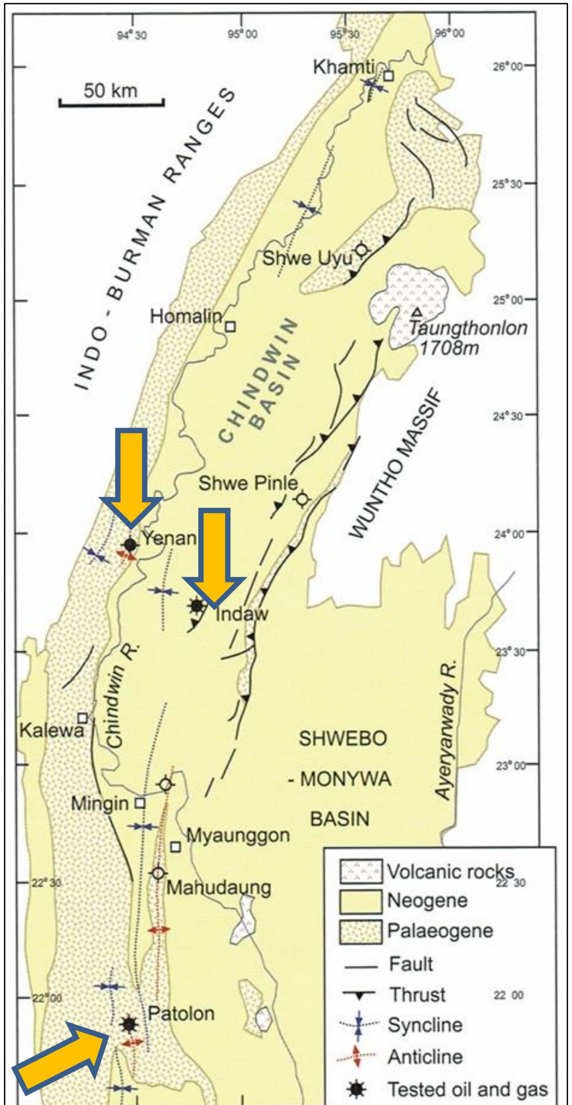
(Pivnik et al, 1998)



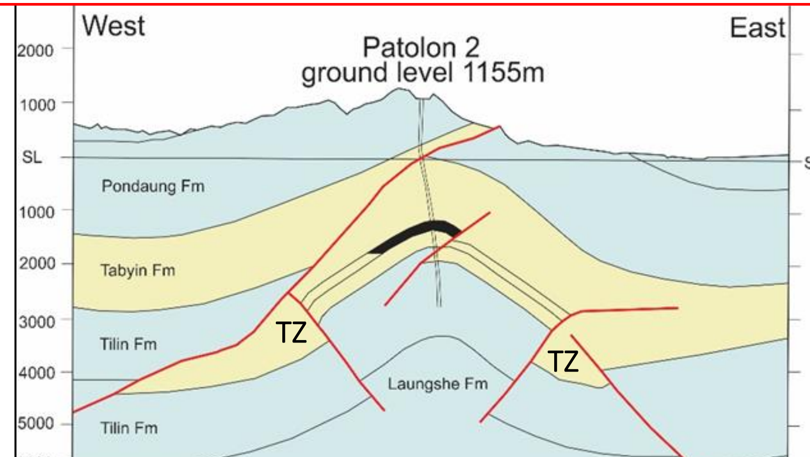


(Pivnik et al, 1998)

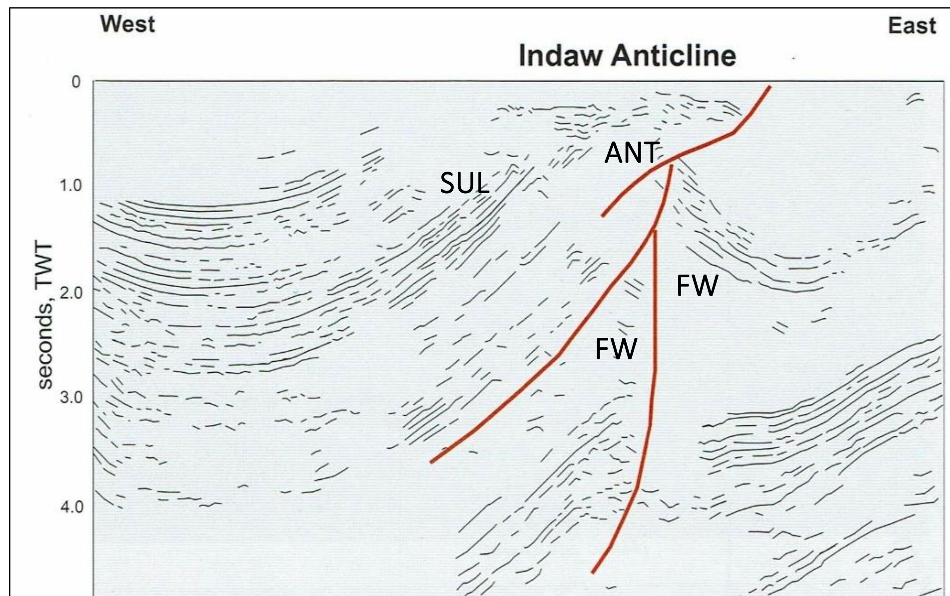
Structure of the Chindwin Sub-basin (CBD) with leads: ANT=anticline, FW=footwall, SUL=sub-unconformity, TZ=triangle zone



(Ridd & Racey, 2015)

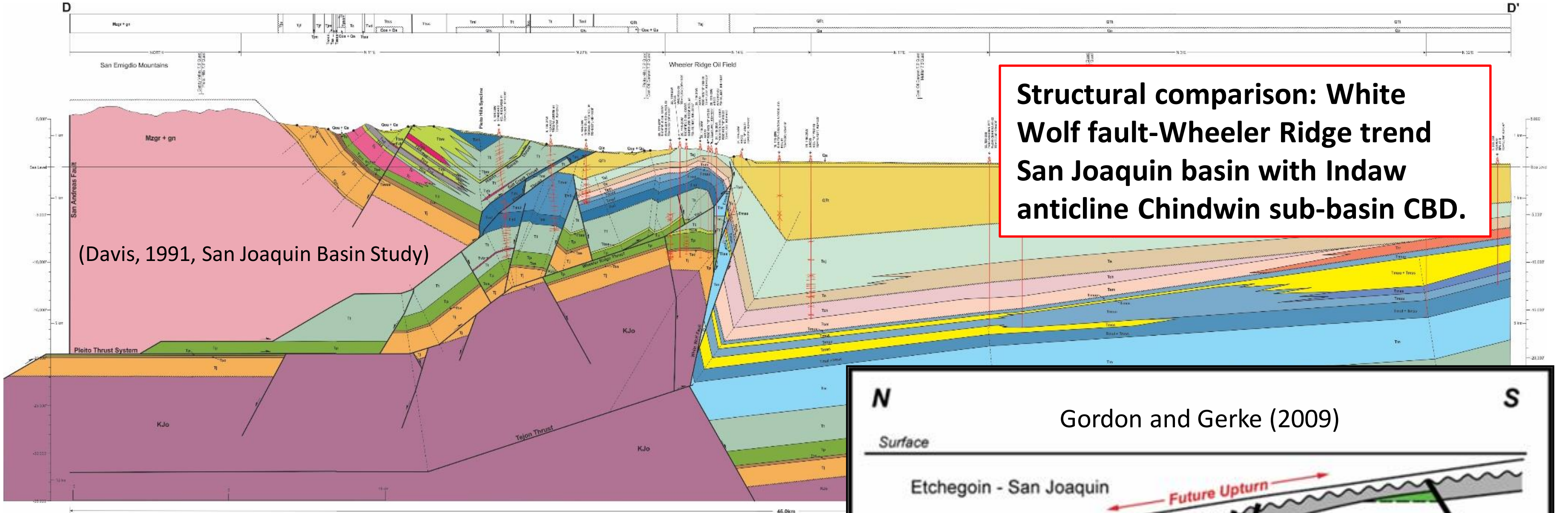


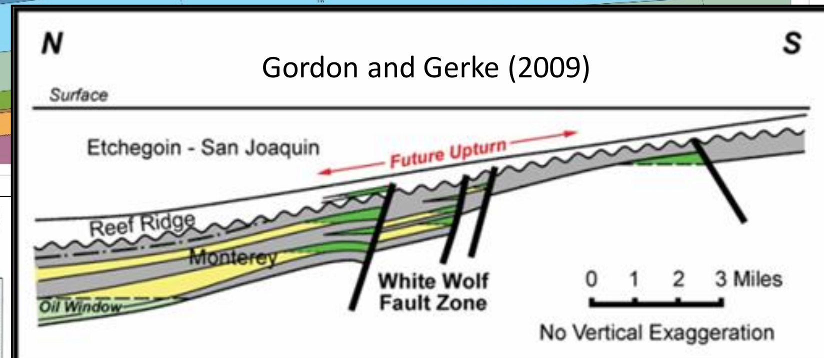
(Ridd & Racey, 2015)



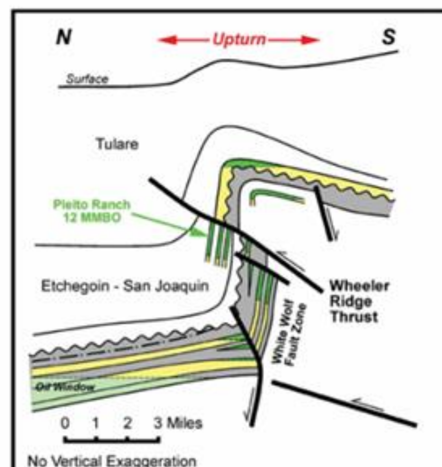
(Ridd & Racey, 2015)

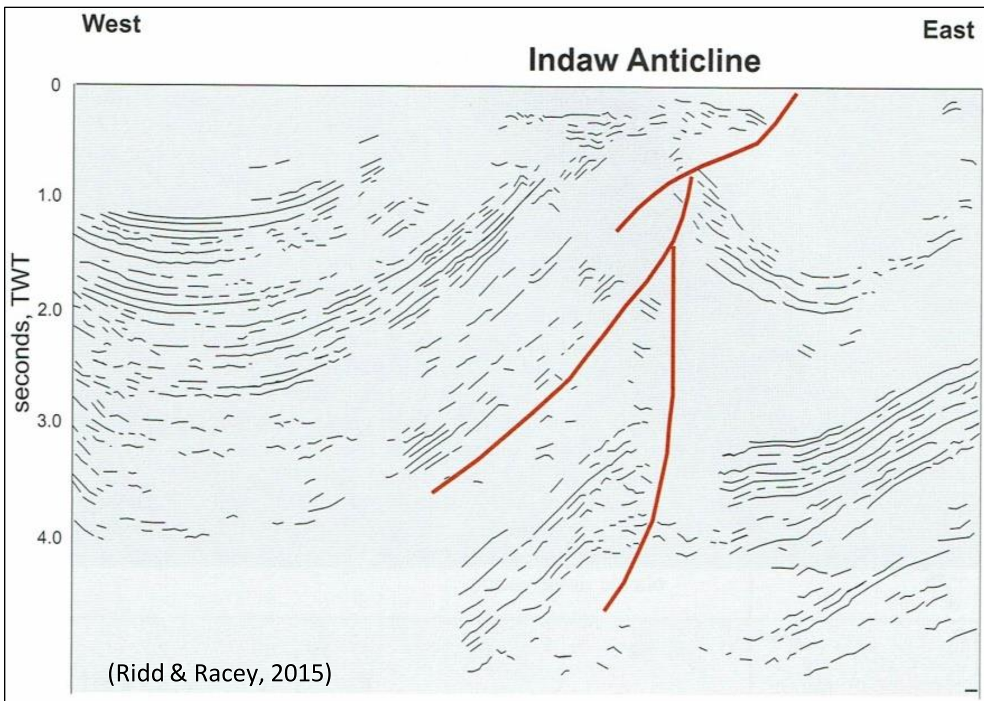
Structural comparison: White Wolf fault-Wheeler Ridge trend San Joaquin basin with Indaw anticline Chindwin sub-basin CBD.



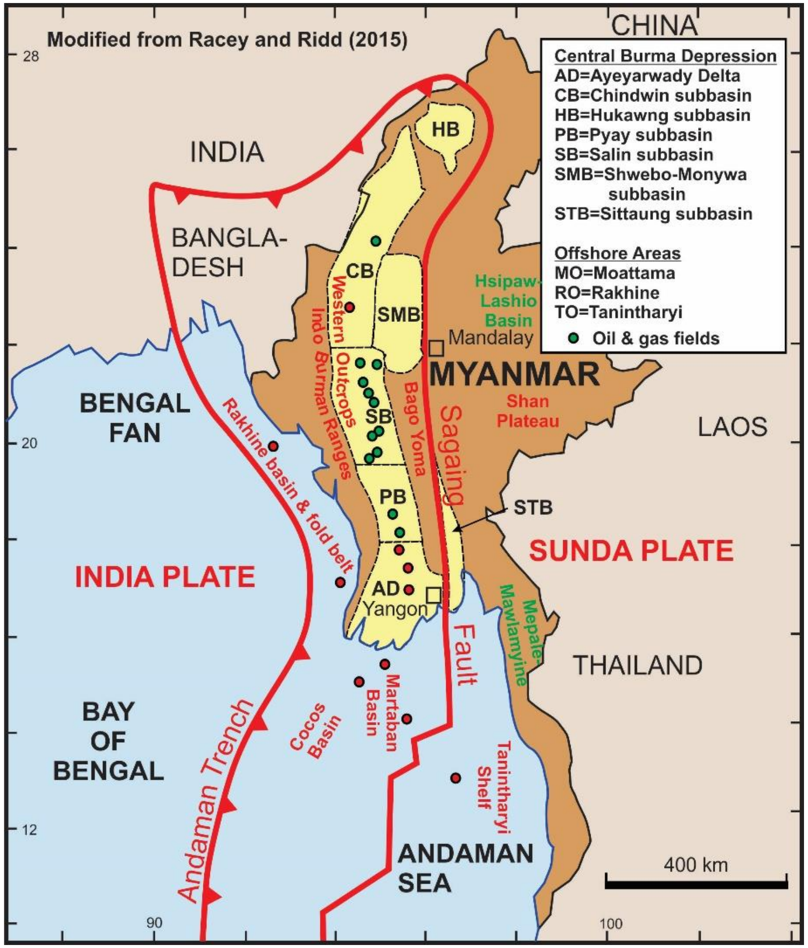


Rotated normal fault





Opportunities, onshore exploration potential



Estimated Tertiary Hydrocarbon Resources in Myanmar

Source: U Kyaw Kyaw Aung MOGE (MOGEC 2015)

ONSHORE — As at 1-4-2015

Sedimentary Basin	OOIP (mmstb)	OGIP (bscf)	Cumulative Production		EFRR	
			Oil (mmstb)	Gas (bcf)	Oil (mmstb)	Gas (bcf)
Chindwin	50.000	11.014	1.200	0.002	8.800	8.808
Shwebo-Monywa	3,255.000		-	-	-	-
Central Myanmar	1,824.766	894.399	566.241	620.812	85.122	130.203
Pyay Embayment	145.002	483.987	40.652	304.531	5.173	89.599
Bago Yoma	-	29.034	-	2.399	-	20.828
Ayeyarwaddy delta	12.126	1,130.946	2.975	652.058	2.847	194.758
Rakhine Coastal	4.500	-	0.009	-	0.881	-
Total (7) Basins	2,036.394	2,549.380	611.077	1,579.802	102.823	444.196

OFFSHORE — As at 1-4-2015

Sedimentary Basin	Offshore Field	Operator	Initial Recoverable Cds (mmstb)	OGIP (tcf)	Initial Recoverable Gas	Cumulative Production		EFRR	
						Cds (mmstb)	Gas (tcf)	Cds (mmstb)	Gas (tcf)
Moattama	Yadana	TEPM	-	6.942	5.893	-	3.686	-	2.207
Taninthari	Yetagun	PCML	84.600	4.166	3.167	48.723	1.917	35.877	1.250
Rakhine	Shwe	Daewoo	-	5.353	4.531	-	0.179	-	4.352
Moattama	Zawtika	PTTEP	-	1.756	1.400	-	0.085	-	1.315
(3) Basins	(4) Fields	(4) Co.,	84.600	18.217	14.991	48.723	5.867	35.877	9.124

(Myint, 2016)

On shore sedimentary basins in Myanmar

- Rakhine deepwater-coastal basin
- Western fold belt and Indo-Burma Ranges (continuation of the Chittagong fold Belt, Bangladesh; Tripura-Cachar Fold belt and Disang Flysch belts, India)
- CBD Tertiary fore-arc (Hukaung, Chindwin, Salin, Pyay, Ayeyarwady), plus CBD Tertiary back-arc (Myitkyina-Katha, Shwebo-Monywa, BagoYoma, Sittaung)
- Eastern intermontaine basins: Tertiary (Putao, Mawlamyine, and Mepale) plus three pre-Tertiary (Hsipaw Lashio, Namyau, Kalaw)

CURRENT PRODUCTION SHARING CONTRACTORS

Currently, 32 international companies from 20 countries are operating in 65 blocks

ONSHORE & OFFSHORE BLOCKS & OPERATORS

Sr No	Nos Of Block ON	Nos Of Block OFF	Names Of Blocks	Names Of Companies	Countries of Companies
1	2		A,E	Nobel Oil	Russia
2	2		B2, EP-3	ONGC Videsh	India
3	2		C1, H	Pacific Hunt Energy	Canada
4	1		F	NPCC	China
5	3	5	G, EP-2, MOGE-3 M-3, M-9, M-11, MD-7, MD-8	PTTEP SA, PTTEPI	Thailand
6	1		I	Jubilant	India
7	2	2	K, RSF-5, MD-2, MD-4	Eni B.V.	Italy
8	1		R	SNOG Pte Ltd	Myanmar
9	1		EP-1	Brunei National	Brunei
10	1		EP-4	Bashneft B.V.	Russia
11	1		EP-5	PT ISTECH	Indonesia
12	2		MOGE-1, IOR-2	Gold Petrol	China
13	4	3	RSF-2 & RSF-3, IOR-5, IOR-7, M-12 M-13,M-14	PCMI/ PCML	Malaysia
14	1		RSF-9	Geopetrol	Switzerland
15	3	1	MOGE-2, IOR-4 & IOR-6 A-6	MPRL	Myanmar
16	1		MOGE-4	CAOG S.a.r.l	Luxembourg
17		3	A-1, A-3, AD-7	Daewoo	Korea
18		4	A-4, A-7, AD-2, AD-5	BG & Woodside	UK, Australia
19		1	A-5	Chevron (Unocal)	USA
20		3	AD-1, AD-6, AD-8	CNPC	China
21		1	AD-3	Ophir	UK
22		3	AD-9, AD-11 MD-5	Shell & MOECO	Netherland
23		1	AD-10	Stat Oil & ConocoPhillips	Norway USA
24		3	YWB, M-5, M-6	Total	France
25		1	M-2	PVEP	Vietnam
26		2	M-4, YEB	Oil India	India
27		1	M-8	Berlanga	Netherland
28		1	M-15	Transcontinental	Australia
29		2	M-17, M-18	Reliance Industries Ltd	India
	28	37	Blocks (Total 65)	Companies (32)	20

2 Onshore Blocks (PSC -J & O) PSC contracts have not been signed yet with Petroleum Exploration Pvt (Pakistan)
1 Offshore Shallow Water Block (M-7) PSC contract has not been signed yet with Tap Oil Ltd (Australia)

(Myint, 2016)

Currently there are 16 onshore blocks and 19 offshore blocks governed by Production Sharing Contracts (PSCs) while three are Improved Petroleum Recovery Contracts (IPR).

Terms:

- Oil and gas operations governed by production-sharing contracts (PSCs) and improved petroleum recovery contracts (IPRCs)
- 12.5 percent royalty to the government
- PSCs, government share of production (through the state-owned company Myanmar Oil and Gas Enterprise, or MOGE) ranges from 60 to 90 percent of profit oil or gas for onshore blocks, depending on production volumes.

Improved Petroleum Recovery Contracts (IPRC)

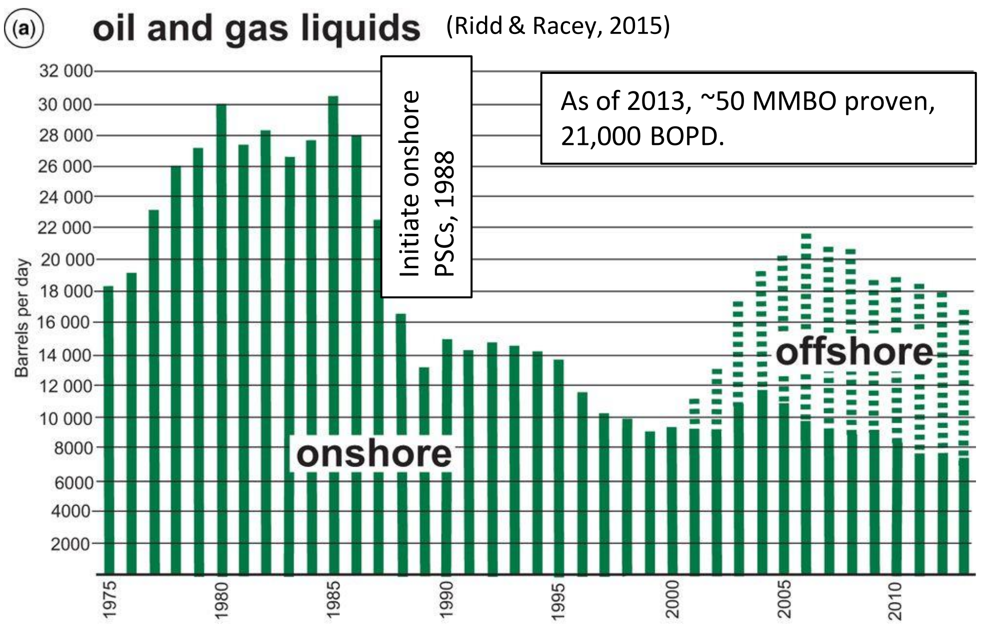
(Myint, 2016)

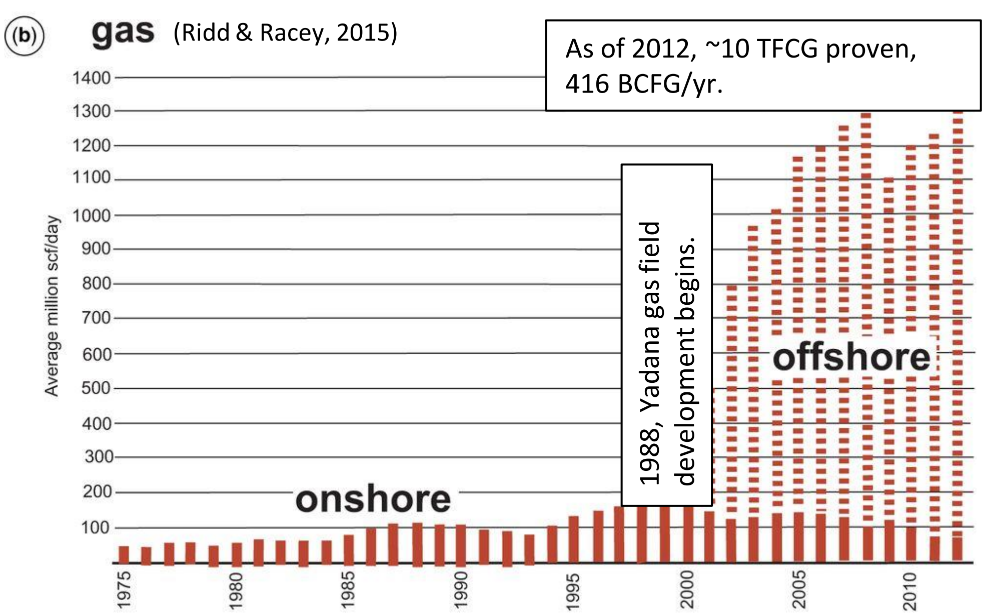
Sr. No	Name of Oil/Gas Field	Discovery Year	Daily Average Production	
			Oil (BOPD)	Gas (MMSCFD)
1	Yenangyaung (Goldpetrol)	1887	1,702	0.3000
2	AYADAW	1893	1	1.6267
3	Chauk/Lanywa(Goldprtrol)	1902	1,456	0.2020
4	Myanaung (MPRL)	1964	36	0.2583
5	Pyay (MPRL)	1965	83	0.1010
6	Shwepyithar (Petronas)	1967	88	0.0400
7	Mann (MPRL)	1970	1,422	2.0042
8	LETPANDO	1974	1,501	0.1270
9	PEPPI	1976	-	0.2024
10	HTAUKSHABIN	1978	526	0.8331
11	KANNI	1985	579	-
12	APYAUK	1991	17	7.5713
13	KYAUKKWET	1995	22	11.0574
14	NYAUNGDON	1999	206	9.5539
15	THARGYITAUNG/SABE	2001	158	2.5820
16	MAUBIN(SOUTH)	2006	75	11.1636
17	HTANGAING/DAHATPIN	2007	16	-
	Onshore Total		7,887	47.6229
18	YADANA	1982	-	516.2440
19	YETAGUN	1992	4,707	224.1090
20	SHWE	2004	-	409.6720
21	ZAWTIKA	2007	-	171.2180
	Offshore Total		4,707	1,321.2430
	Grand Total		12,594	1,368.8659

Terms:

- Oil and gas operations governed by production-sharing contracts (PSCs) and improved petroleum recovery contracts (IPRCs)
- 12.5 percent royalty to the government
- IPRC for onshore blocks, the government share of production ranges from 60 to 85 percent for profit oil and is 60 percent for profit gas. MOGE, is also entitled to equity participation, ranging from 15 to 25 percent, depending on the model contract.

Myanmar oil & gas, production and exploration





Myanmar's onshore oil production has decreased significantly since the mid-1980s while offshore gas and oil have increased since 2000.

Conclusions:

- Myanmar has remaining exploration potential in the CBD and the numerous unexplored basins.
- CBD oil field traps and fold and thrust belt structural style probably result from strain partitioning, and exploration techniques used in California's oil basins could increase the number of prospects and eventually production.
- Potential stratigraphic traps in the CBD and elsewhere need attention. Synorogenic sedimentation results in growth strata and unconformities that provide additional trapping mechanisms.
- Deep depocenters are common to all of California's oil basins and are key to source rock generation. CBD has deep depocenters.
- Coeval deformation and source rock generation will alter migration pathways.
- Many of the onshore fields are very old and in need of reinvestment and application of EOR techniques should significantly increase oil and gas production.
- Gas storage fields are needed to expand domestic energy needs.

END OF PRESENTATION

References

Davis, T.L., M.B. Lagoe, W.J.M. Bazeley, S. Gordon, K. McIntosh, and J.S. Namson, 1988, Structure of the Cuyama Valley, Caliente Range, and Carrizo Plain and its significance to the structural style of the southern Coast Ranges and western Transverse Ranges, in W.J.M. Bazeley, ed., Tertiary tectonics and sedimentation in the Cuyama basin, San Luis Obispo, Santa Barbara, and Ventura Counties, CA: PSSEPM, v. 59, p. 141-158.

______, Namson, J.S., and Gordon, S.A., 1996, Structure and hydrocarbon exploration in the Transpressive basins of southern California, in P.L. Abbott and J.D. Cooper, eds., Field conference guide 1996, PSSEPM, Book 80, and PSAAPG, GB 73, p. 189-238.

Davis, T.L. and Namson, J.A., 2017, Petroleum traps and structures along the San Andreas convergent strike-slip plate boundary, California: AAPG Bulletin, v. 101, no. 4 (April 2017), pp. 607–615.

Dickenson, W.R., 1981, Plate tectonic evolution of the southern Cordillera: in relations of tectonics to ore deposits in the southern Cordillera, Arizona Geological Society Digest, 14, p. 113-135.

Gordon, S.A. and H.J. Gerke, 2009, Controls on petroleum occurrence and exploration prospectiveness in the southernmost San Joaquin Basin, California, in L.C. Knauer and A. Britton, eds, Contributions to the geology of the San Joaquin Basin, CA, PS AAPG, MP 48, p.19-50.

Jamison, W.R., 1983, Mechanical Stability of the Triangle Zone: The Backthrust Wedge: Journal of Geophysical Research, v. 98, no B11, p. 20,015-20,030.

Lowell, J.D., 1972, Spitsbergen Tertiary orogenic belt and Spitsbergen fracture zone: GSA Bulletin, v. 83, p. 3091-3101.

Mount, V.S. and J. Suppe, 1987, State of stress near the San Andreas fault: implications for wrench tectonics: Geology, v.15, p.1143-1146.

Myint, L. 2016, A Synthesis of Myanmar Petroleum Geology and Potential, Adapted from oral presentation given at The Second AAPG/EAGE/MGS Conference Innovation in Geoscience: Unlocking the Complex Geology of Myanmar, Yangon, Myanmar, November 19-20, 2015 AAPG Search and Discovery Article #30453 (2016).

Namson, J.S. and T.L. Davis, 1988, Seismically active fold and thrust belt in the San Joaquin Valley, central California: GSA Bulletin, v.100, p. 257-273.

Pivnik, D.A., J. Nahm, R.S.Tucker, G.O. Smith, K.Nyein, M. Nyunt, and P. H. Maung, 1998, Polyphase Deformation in a Fore-Arc/Back-Arc Basin, Salin Subbasin, Myanmar (Burma), AAPG Bulletin, V. 82, No. 10 (October 1998), P. 1837–1856.

Racey, A. and Ridd, M.F., 2015, Petroleum Geology of Myanmar, Geological Society Memoir No. 45, The Geological Society of London, 123 p.

Sanderson D. J., Marchini W.R.D. (1984) Transpression, Journal of Structural Geology 6:449–458

Searle, M. and Morley, 2011, Tectonics and Thermal evolution of Thailand in the regional context of South-East Asia. Geology of Thailand, in The Geology of Thailand (pp.539-571) Chapter: 20 Geological Society of London, Editors: Ridd, M. F., Barber, A. J., Crow, M. J.

References (cont.)

Suppe, J., and D.A. Medwedeff, 1990, Geometry and kinematics of fault-propagation folding: Eclogae. geol. Helv., v. 83/3 (Laubscher Volume), p. 409-454.

Than Htut,2017, Myanmar petroleum systems, including the offshore area, in Chapter 11 Myanmar, Geological Society, London, Memoirs, 48, 219-260, 2017, https://doi.org/10.1144/M48.11

USGS, 2017, Back to the Future on the San Andreas Fault, https://www.usgs.gov/natural-hazards/earthquake-hazards/science/back-future-san-andreas-fault?qt-science_center_objects=0#qt-science_center_objects

Vestrum, R., Gonguet, C. and MacArthur, T., 2017, Geologically Constrained Anisotropic Depth Imaging in the Central Burma Basin, Onshore Myanmar, CSEG Recorder, v. 42 no. 06, p. 20-22, ,https://csegrecorder.com/articles/view/geologically-constrained-anisotropic-depth-imaging-in-the-central-burma-bas

Wallace, R.E., 1990, The San Andreas fault system, California. U.S. Geological Survey Professional Paper: 1515.